

07



Copyright and  
Corporate Affairs Canada

Commission  
et Corporations Canada

(11) (A) No. 1 168 283

(45) ISSUED 840529

(52) CLASS 309-6

(51) INT. CL. H05B 3/03,3/46

(19) (CA) **CANADIAN PATENT** (12)

(54) ELECTRODE DEVICE FOR ELECTRICALLY HEATING UNDERGROUND  
DEPOSITS OF HYDROCARBONS

(72) Inoue, Takeo;  
Teratani, Hiroshi;  
Kobayashi, Toshiyuki,  
Japan

(73) Granted to Mitsubishi Denki Kabushiki Kaisha  
Japan

(21) APPLICATION No. 375,295

(22) FILED 810413

(30) PRIORITY DATA Japan (51153/80) 800414  
Japan (51173/80) 800414  
Japan (51174/80) 800414

NO. OF CLAIMS 11

Canada

DISCLOSED BY THE PATENT OFFICE OF CANADA  
C-274 (1/82)

1168283

FIG. 1 (PRIOR ART)

3-1

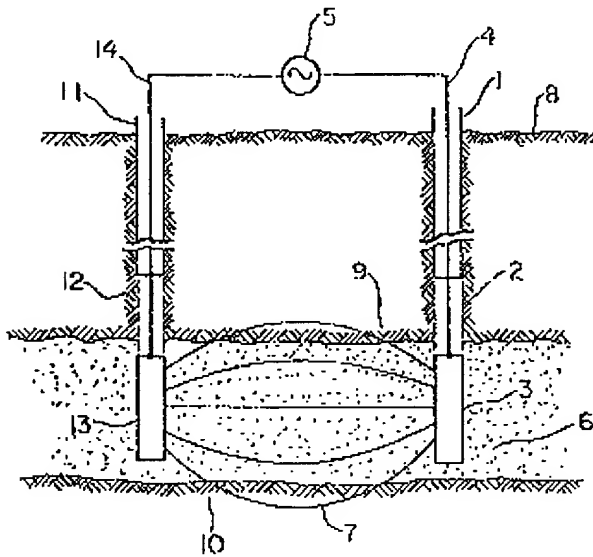
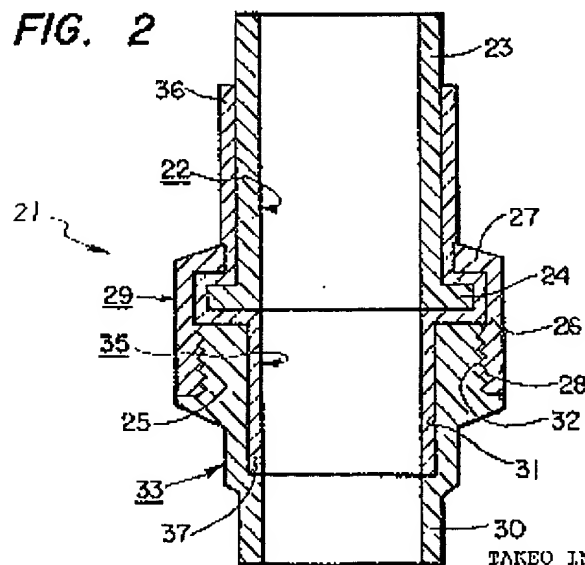


FIG. 2



TAKEO INOUE  
HIROSHI TERATANI  
TOSHIYUKI KOBAYASHI  
Inventors

*Richard M. Langner & Hubert*  
Attorney

1168283

3-2

FIG. 3

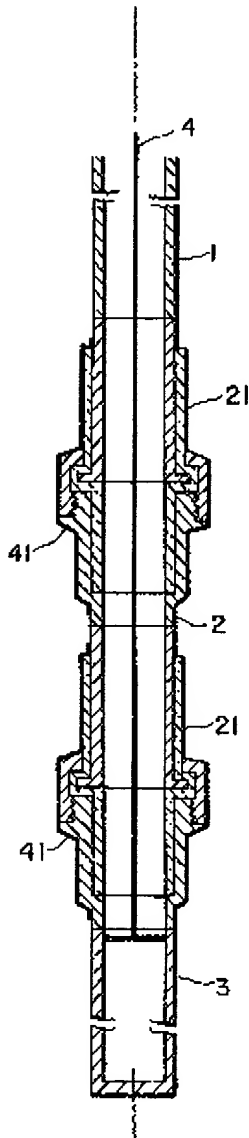


FIG. 4

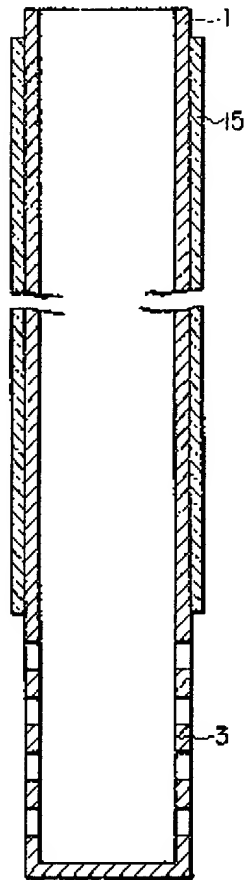
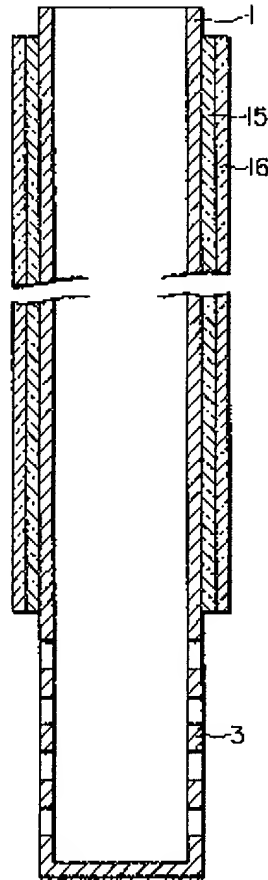


FIG. 5



TAKAO INOUE  
HIROSHI TERATANI  
TOSHIYUKI KOBAYASHI  
Inventors

*Richard M. Hughes & Harbort*  
Attorney

1168283

3-3

FIG. 6

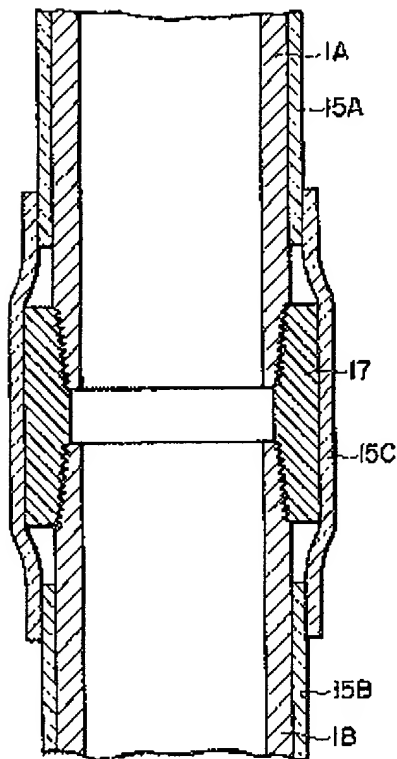
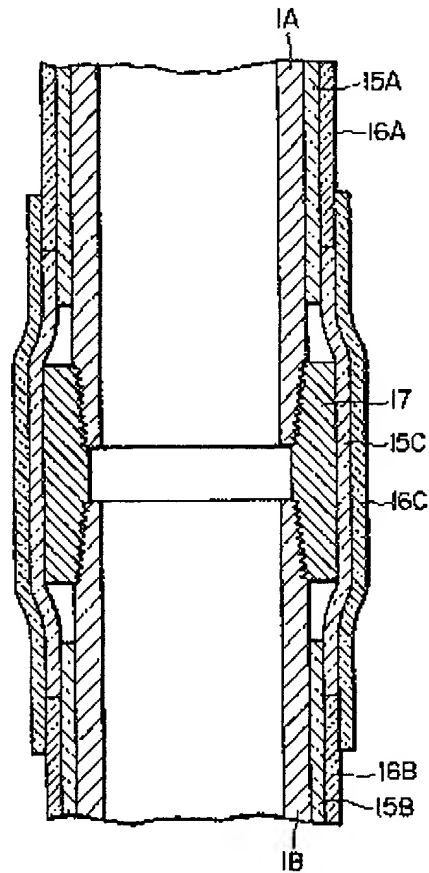


FIG. 7



TAKEO INOUE  
HIROSHI TERATANI  
TOSHIYUKI KODAYASHI  
Inventors

*Richard M. Thayer & Herbert*  
Attorney

ABSTRACT OF THE DISCLOSURE

An electrode device for electrically heating underground deposits of hydrocarbons such as oil sand or oil shale. Plural well pipe sections are joined through insulated pipe joints with an electrode connected through one of the insulated pipe joints to a lower one of the pipe sections. Each of the insulated pipe joints includes a first tubular member having a flange portion at one end thereof, a second tubular member having a cap portion at one end which is received in the flange portion of the first tubular member with a gap therebetween, and an insulating member disposed in the gap for hermetically coupling the first and second tubular members and for electrically insulating first and second tubular members from one another.

1168283

ELECTRODE DEVICE FOR ELECTRICALLY HEATING  
UNDERGROUND DEPOSITS OF HYDROCARBONS

BACKGROUND OF THE INVENTION

The present invention relates to an electric device used to electrically heat underground deposits of hydrocarbons. More specifically, the present invention relates to an electrode device which is used to supply electrical power to an underground deposit thereby to heat the hydrocarbons present in the deposit to cause them to have a lower viscosity and higher fluidity in order to more easily remove them from the well.

The term "hydrocarbons" as used hereinafter means petroleum or oil, bitumen contained in oil sand (also called "tar sand") and kerogen contained in oil shale. These will all be referred to as "oil" for simplicity.

If the oil in the underground deposit has sufficient fluidity, it is possible to extract the oil through the well either by gas pressure coexisting in the oil layer or by forcing a liquid such as brine into one well to force the oil to flow out of another well. However, should the underground oil have low fluidity, it cannot be extracted until the oil is made more fluid. A general method of making the oil fluid is to heat the oil thereby to lower the viscosity of the oil. The temperature suitable for this is different for different types of oil.

There have been proposed as oil layer heating methods

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60  
61  
62  
63  
64  
65  
66  
67  
68  
69  
70  
71  
72  
73  
74  
75  
76  
77  
78  
79  
80  
81  
82  
83  
84  
85  
86  
87  
88  
89  
90  
91  
92  
93  
94  
95  
96  
97  
98  
99  
100  
101  
102  
103  
104  
105  
106  
107  
108  
109  
110  
111  
112  
113  
114  
115  
116  
117  
118  
119  
120  
121  
122  
123  
124  
125  
126  
127  
128  
129  
130  
131  
132  
133  
134  
135  
136  
137  
138  
139  
140  
141  
142  
143  
144  
145  
146  
147  
148  
149  
150  
151  
152  
153  
154  
155  
156  
157  
158  
159  
160  
161  
162  
163  
164  
165  
166  
167  
168  
169  
170  
171  
172  
173  
174  
175  
176  
177  
178  
179  
180  
181  
182  
183  
184  
185  
186  
187  
188  
189  
190  
191  
192  
193  
194  
195  
196  
197  
198  
199  
200  
201  
202  
203  
204  
205  
206  
207  
208  
209  
210  
211  
212  
213  
214  
215  
216  
217  
218  
219  
220  
221  
222  
223  
224  
225  
226  
227  
228  
229  
230  
231  
232  
233  
234  
235  
236  
237  
238  
239  
240  
241  
242  
243  
244  
245  
246  
247  
248  
249  
250  
251  
252  
253  
254  
255  
256  
257  
258  
259  
260  
261  
262  
263  
264  
265  
266  
267  
268  
269  
270  
271  
272  
273  
274  
275  
276  
277  
278  
279  
280  
281  
282  
283  
284  
285  
286  
287  
288  
289  
290  
291  
292  
293  
294  
295  
296  
297  
298  
299  
300  
301  
302  
303  
304  
305  
306  
307  
308  
309  
310  
311  
312  
313  
314  
315  
316  
317  
318  
319  
320  
321  
322  
323  
324  
325  
326  
327  
328  
329  
330  
331  
332  
333  
334  
335  
336  
337  
338  
339  
340  
341  
342  
343  
344  
345  
346  
347  
348  
349  
350  
351  
352  
353  
354  
355  
356  
357  
358  
359  
360  
361  
362  
363  
364  
365  
366  
367  
368  
369  
370  
371  
372  
373  
374  
375  
376  
377  
378  
379  
380  
381  
382  
383  
384  
385  
386  
387  
388  
389  
390  
391  
392  
393  
394  
395  
396  
397  
398  
399  
400  
401  
402  
403  
404  
405  
406  
407  
408  
409  
410  
411  
412  
413  
414  
415  
416  
417  
418  
419  
420  
421  
422  
423  
424  
425  
426  
427  
428  
429  
430  
431  
432  
433  
434  
435  
436  
437  
438  
439  
440  
441  
442  
443  
444  
445  
446  
447  
448  
449  
450  
451  
452  
453  
454  
455  
456  
457  
458  
459  
460  
461  
462  
463  
464  
465  
466  
467  
468  
469  
470  
471  
472  
473  
474  
475  
476  
477  
478  
479  
480  
481  
482  
483  
484  
485  
486  
487  
488  
489  
490  
491  
492  
493  
494  
495  
496  
497  
498  
499  
500  
501  
502  
503  
504  
505  
506  
507  
508  
509  
510  
511  
512  
513  
514  
515  
516  
517  
518  
519  
520  
521  
522  
523  
524  
525  
526  
527  
528  
529  
530  
531  
532  
533  
534  
535  
536  
537  
538  
539  
540  
541  
542  
543  
544  
545  
546  
547  
548  
549  
550  
551  
552  
553  
554  
555  
556  
557  
558  
559  
560  
561  
562  
563  
564  
565  
566  
567  
568  
569  
570  
571  
572  
573  
574  
575  
576  
577  
578  
579  
580  
581  
582  
583  
584  
585  
586  
587  
588  
589  
590  
591  
592  
593  
594  
595  
596  
597  
598  
599  
600  
601  
602  
603  
604  
605  
606  
607  
608  
609  
610  
611  
612  
613  
614  
615  
616  
617  
618  
619  
620  
621  
622  
623  
624  
625  
626  
627  
628  
629  
630  
631  
632  
633  
634  
635  
636  
637  
638  
639  
640  
641  
642  
643  
644  
645  
646  
647  
648  
649  
650  
651  
652  
653  
654  
655  
656  
657  
658  
659  
660  
661  
662  
663  
664  
665  
666  
667  
668  
669  
670  
671  
672  
673  
674  
675  
676  
677  
678  
679  
680  
681  
682  
683  
684  
685  
686  
687  
688  
689  
690  
691  
692  
693  
694  
695  
696  
697  
698  
699  
700  
701  
702  
703  
704  
705  
706  
707  
708  
709  
710  
711  
712  
713  
714  
715  
716  
717  
718  
719  
720  
721  
722  
723  
724  
725  
726  
727  
728  
729  
730  
731  
732  
733  
734  
735  
736  
737  
738  
739  
740  
741  
742  
743  
744  
745  
746  
747  
748  
749  
750  
751  
752  
753  
754  
755  
756  
757  
758  
759  
760  
761  
762  
763  
764  
765  
766  
767  
768  
769  
770  
771  
772  
773  
774  
775  
776  
777  
778  
779  
780  
781  
782  
783  
784  
785  
786  
787  
788  
789  
790  
791  
792  
793  
794  
795  
796  
797  
798  
799  
800  
801  
802  
803  
804  
805  
806  
807  
808  
809  
810  
811  
812  
813  
814  
815  
816  
817  
818  
819  
820  
821  
822  
823  
824  
825  
826  
827  
828  
829  
830  
831  
832  
833  
834  
835  
836  
837  
838  
839  
840  
841  
842  
843  
844  
845  
846  
847  
848  
849  
850  
851  
852  
853  
854  
855  
856  
857  
858  
859  
860  
861  
862  
863  
864  
865  
866  
867  
868  
869  
870  
871  
872  
873  
874  
875  
876  
877  
878  
879  
880  
881  
882  
883  
884  
885  
886  
887  
888  
889  
890  
891  
892  
893  
894  
895  
896  
897  
898  
899  
900  
901  
902  
903  
904  
905  
906  
907  
908  
909  
910  
911  
912  
913  
914  
915  
916  
917  
918  
919  
920  
921  
922  
923  
924  
925  
926  
927  
928  
929  
930  
931  
932  
933  
934  
935  
936  
937  
938  
939  
940  
941  
942  
943  
944  
945  
946  
947  
948  
949  
950  
951  
952  
953  
954  
955  
956  
957  
958  
959  
960  
961  
962  
963  
964  
965  
966  
967  
968  
969  
970  
971  
972  
973  
974  
975  
976  
977  
978  
979  
980  
981  
982  
983  
984  
985  
986  
987  
988  
989  
990  
991  
992  
993  
994  
995  
996  
997  
998  
999  
1000  
1001  
1002  
1003  
1004  
1005  
1006  
1007  
1008  
1009  
1010  
1011  
1012  
1013  
1014  
1015  
1016  
1017  
1018  
1019  
1020  
1021  
1022  
1023  
1024  
1025  
1026  
1027  
1028  
1029  
1030  
1031  
1032  
1033  
1034  
1035  
1036  
1037  
1038  
1039  
1040  
1041  
1042  
1043  
1044  
1045  
1046  
1047  
1048  
1049  
1050  
1051  
1052  
1053  
1054  
1055  
1056  
1057  
1058  
1059  
1060  
1061  
1062  
1063  
1064  
1065  
1066  
1067  
1068  
1069  
1070  
1071  
1072  
1073  
1074  
1075  
1076  
1077  
1078  
1079  
1080  
1081  
1082  
1083  
1084  
1085  
1086  
1087  
1088  
1089  
1090  
1091  
1092  
1093  
1094  
1095  
1096  
1097  
1098  
1099  
1100  
1101  
1102  
1103  
1104  
1105  
1106  
1107  
1108  
1109  
1110  
1111  
1112  
1113  
1114  
1115  
1116  
1117  
1118  
1119  
1120  
1121  
1122  
1123  
1124  
1125  
1126  
1127  
1128  
1129  
1130  
1131  
1132  
1133  
1134  
1135  
1136  
1137  
1138  
1139  
1140  
1141  
1142  
1143  
1144  
1145  
1146  
1147  
1148  
1149  
1150  
1151  
1152  
1153  
1154  
1155  
1156  
1157  
1158  
1159  
1160  
1161  
1162  
1163  
1164  
1165  
1166  
1167  
1168  
1169  
1170  
1171  
1172  
1173  
1174  
1175  
1176  
1177  
1178  
1179  
1180  
1181  
1182  
1183  
1184  
1185  
1186  
1187  
1188  
1189  
1190  
1191  
1192  
1193  
1194  
1195  
1196  
1197  
1198  
1199  
1200  
1201  
1202  
1203  
1204  
1205  
1206  
1207  
1208  
1209  
1210  
1211  
1212  
1213  
1214  
1215  
1216  
1217  
1218  
1219  
1220  
1221  
1222  
1223  
1224  
1225  
1226  
1227  
1228  
1229  
1230  
1231  
1232  
1233  
1234  
1235  
1236  
1237  
1238  
1239  
1240  
1241  
1242  
1243  
1244  
1245  
1246  
1247  
1248  
1249  
1250  
1251  
1252  
1253  
1254  
1255  
1256  
1257  
1258  
1259  
1260  
1261  
1262  
1263  
1264  
1265  
1266  
1267  
1268  
1269  
1270  
1271  
1272  
1273  
1274  
1275  
1276  
1277  
1278  
1279  
1280  
1281  
1282  
1283  
1284  
1285  
1286  
1287  
1288  
1289  
1290  
1291  
1292  
1293  
1294  
1295  
1296  
1297  
1298  
1299  
1300  
1301  
1302  
1303  
1304  
1305  
1306  
1307  
1308  
1309  
1310  
1311  
1312  
1313  
1314  
1315  
1316  
1317  
1318  
1319  
1320  
1321  
1322  
1323  
1324  
1325  
1326  
1327  
1328  
1329  
1330  
1331  
1332  
1333  
1334  
1335  
1336  
1337  
1338  
1339  
1340  
1341  
1342  
1343  
1344  
1345  
1346  
1347  
1348  
1349  
1350  
1351  
1352  
1353  
1354  
1355  
1356  
1357  
1358  
1359  
1360  
1361  
1362  
1363  
1364  
1365  
1366  
1367  
1368  
1369  
1370  
1371  
1372  
1373  
1374  
1375  
1376  
1377  
1378  
1379  
1380  
1381  
1382  
1383  
1384  
1385  
1386  
1387  
1388  
1389  
1390  
1391  
1392  
1393  
1394  
1395  
1396  
1397  
1398  
1399  
1400  
1401  
1402  
1403  
1404  
1405  
1406  
1407  
1408  
1409  
1410  
1411  
1412  
1413  
1414  
1415  
1416  
1417  
1418  
1419  
1420  
1421  
1422  
1423  
1424  
1425  
1426  
1427  
1428  
1429  
1430  
1431  
1432  
1433  
1434  
1435  
1436  
1437  
1438  
1439  
1440  
1441  
1442  
1443  
1444  
1445  
1446  
1447  
1448  
1449  
1450  
1451  
1452  
1453  
1454  
1455  
1456  
1457  
1458  
1459  
1460  
1461  
1462  
1463  
1464  
1465  
1466  
1467  
1468  
1469  
1470  
1471  
1472  
1473  
1474  
1475  
1476  
1477  
1478  
1479  
1480  
1481  
1482  
1483  
1484  
1485  
1486  
1487  
1488  
1489  
1490  
1491  
1492  
1493  
1494  
1495  
1496  
1497  
1498  
1499  
1500  
1501  
1502  
1503  
1504  
1505  
1506  
1507  
1508  
1509  
1510  
1511  
1512  
1513  
1514  
1515  
1516  
1517  
1518  
1519  
1520  
1521  
1522  
1523  
1524  
1525  
1526  
1527  
1528  
1529  
1530  
1531  
1532  
1533  
1534  
1535  
1536  
1537  
1538  
1539  
1540  
1541  
1542  
1543  
1544  
1545  
1546  
1547  
1548  
1549  
1550  
1551  
1552  
1553  
1554  
1555  
1556  
1557  
1558  
1559  
1560  
1561  
1562  
1563  
1564  
1565  
1566  
1567  
1568  
1569  
1570  
1571  
1572  
1573  
1574  
1575  
1576  
1577  
1578  
1579  
1580  
1581  
1582  
1583  
1584  
1585  
1586  
1587  
1588  
1589  
1590  
1591  
1592  
1593  
1594  
1595  
1596  
1597  
1598  
1599  
1600  
1601  
1602  
1603  
1604  
1605  
1606  
1607  
1608  
1609  
1610  
1611  
1612  
1613  
1614  
1615  
1616  
1617  
1618  
1619  
1620  
1621  
1622  
1623  
1624  
1625  
1626  
1627  
1628  
1629  
1630  
1631  
1632  
1633  
1634  
1635  
1636  
1637  
1638  
1639  
1640  
1641  
1642  
1643  
1644  
1645  
1646  
1647  
1648  
1649  
1650  
1651  
1652  
1653  
1654  
1655  
1656  
1657  
1658  
1659  
1660  
1661  
1662  
1663  
1664  
1665  
1666  
1667  
1668  
1669  
1670  
1671  
1672  
1673  
1674  
1675  
1676  
1677  
1678  
1679  
1680  
1681  
1682  
1683  
1684  
1685  
1686  
1687  
1688  
1689  
1690  
1691  
1692  
1693  
1694  
1695  
1696  
1697  
1698  
1699  
1700  
1701  
1702  
1703  
1704  
1705  
1706  
1707  
1708  
1709  
1710  
1711  
1712  
1713  
1714  
1715  
1716  
1717  
1718  
1719  
1720  
1721  
1722  
1723  
1724  
1725  
1726  
1727  
1728  
1729  
1730  
1731  
1732  
1733  
1734  
1735  
1736  
1737  
1738  
1739  
1740  
1741  
1742  
1743  
1744  
1745  
1746  
1747  
1748  
1749  
1750  
1751  
1752  
1753  
1754  
1755  
1756  
1757  
1758  
1759  
1760  
1761  
1762  
1763  
1764  
1765  
1766  
1767  
1768  
1769  
1770  
1771  
1772  
1773  
1774  
1775  
1776  
1777  
1778  
1779  
1780  
1781  
1782  
1783  
1784  
1785  
1786  
1787  
1788  
1789  
1790  
1791  
1792  
1793  
1794  
1795  
1796  
1797  
1798  
1799  
1800  
1801  
1802  
1803  
1804  
1805  
1806  
1807  
1808  
1809  
1810  
1811  
1812  
1813  
1814  
1815  
1816  
1817  
1818  
1819  
1820  
1821  
1822  
1823  
1824  
1825  
1826  
1827  
1828  
1829  
1830  
1831  
1832  
1833  
1834  
1835  
1836  
1837  
1838  
1839  
1840  
1841  
1842  
1843  
1844  
1845  
1846  
1847  
1848  
1849  
1850  
1851  
1852  
1853  
1854  
1855  
1856  
1857  
1858  
1859  
1860  
1861  
1862  
1863  
1864  
1865  
1866  
1867  
1868  
1869  
1870  
1871  
1872  
1873  
1874  
1875  
1876  
1877  
1878  
1879  
1880  
1881  
1882  
1883  
1884  
1885  
1886  
1887  
1888  
1889  
1890  
1891  
1892  
1893  
1894  
1895  
1896  
1897  
1898  
1899  
1900  
1901  
1902  
1903  
1904  
1905  
1906  
1907  
1908  
1909  
1910  
1911  
1912  
1913  
1914  
1915  
1916  
1917  
1918  
1919  
1920  
1921  
1922  
1923  
1924  
1925  
1926  
1927  
1928  
1929  
1930  
1931  
1932  
1933  
1934  
1935  
1936  
1937  
1938  
1939  
1940  
1941  
1942  
1943  
1944  
1945  
1946  
1947  
1948  
1949  
1950  
1951  
1952  
1953  
1954  
1955  
1956  
1957  
1958  
1959  
1960  
1961  
1962  
1963  
1964  
1965  
1966  
1967  
1968  
1969  
1970  
1971  
1972  
1973  
1974  
1975  
1976  
1977  
1978  
1979  
1980  
1981  
1982  
1983  
1984  
1985  
1986  
1987  
1988  
1989  
1990  
1991  
1992  
1993  
1994  
1995  
1996  
1997  
1998  
1999  
2000  
2001  
2002  
2003  
2004  
2005  
2006  
2007  
2008  
2009  
2010  
2011  
2012  
2013  
2014  
2015  
2016  
2017  
2018  
2019  
2020  
2021  
2022  
2023  
2024  
2025  
2026  
2027  
2028  
2029  
2030  
2031  
2032  
2033  
2034  
2035  
2036  
2037  
2038  
2039  
2040  
2041  
2042  
2043  
2044  
2045  
2046  
2047  
2048  
2049  
2050  
2051  
2052  
2053  
2054  
2055  
2056  
2057  
2058  
2059  
2060  
2061  
2062  
2063  
2064  
2065  
2066  
2067  
2068  
2069  
2070  
2071  
2072  
2073  
2074  
2075  
2076  
2077  
2078  
2079  
2080  
2081  
2082  
2083  
2084  
2085  
2086  
2087  
2088  
2089  
2090  
2091  
2092  
2093  
2094  
2095  
2096  
2097  
2098  
2099  
2100  
2101  
2102  
2103  
2104  
2105  
2106  
2107  
2108  
2109  
2110  
2111  
2112  
2113  
2114  
2115  
2116  
2117  
2118  
2119  
2120  
2121  
2122  
2123  
2124  
2125  
2126  
2127  
2128  
2129  
2130  
2131  
2132  
2133  
2134  
2135  
2136  
2137  
2138  
2139  
2140  
2141  
2142  
2143  
2144  
2145  
2146  
2147  
2148  
2149  
2150  
2151  
2152  
2153  
2154  
2155  
2156  
2157  
215

1168283

the injection of hot water or water vapors at a high temperature under a high pressure, supplying electrical power to the underground deposit, underground combustion in which the underground oil layer is ignited with a supply of air so that it may be burned, and the use of explosives. The last two methods are difficult to control so that they are not in general use.

According to the method of injecting the hot water or water vapor at a high temperature and under a high pressure, the oil layer is heated to enhance the fluidity of the oil to cause the fluid oil to flow out to the ground surface. If, however, some regions of the oil deposit have a low resistance to the flow of hot water or water vapors or there are voids in the oil layer, the water or vapors may collect in these regions and fail to diffuse throughout the whole layer. Moreover, if the oil layer is solid and dense, the hot water or its vapors will again not diffuse so that the oil layer cannot be heated.

Heating by the supply of electrical power is performed by drilling a plurality of wells in the oil layer and by establishing potential differences between electrodes disposed in the wells so that the oil layer is heated by its resistance to the electrical current which flows therethrough. This technique is advantageous in that the oil layer can be wholly heated with ease even if it has voids or is solid and dense. However, another device is required for pumping up the fluid oil.

For improving the oil producing efficiency, there has

further been proposed a method which includes a first step of heating the oil layer by electrical resistance heating and a step of injecting hot water or water vapors at a high temperature and under a high pressure when the oil layer becomes soft while continuing the heating so that the resultant fluid oil may be pumped out. In order to efficiently heat the oil layer, the electrode device must be sufficiently electrically insulated that the leakage of electrically current into underground portions other than the oil layer is avoided as much as possible. The electrode device is also required to be unbreakable with respect to the underground soil pressure, the pressure of the vapors which are generated by the heating operation, and the pressure of injected hot water or hot high pressure water vapors. The electrode device is further required to be free from leakage of hot water or hot high pressure water vapors.

In order to explain, the electrode device of this general type more fully, an example in which the oil is extracted from oil sand will be described.

Oil sand, also called "tar sand", is present in large quantities in Canada, Venezuela and the United States. The oil in the oil sand is typically mixed with brine between sands in deposits. Moreover, it typically has such a remarkably high viscosity that it has essentially no fluidity in its natural state. A deposit of the oil sand may be partially exposed in a valley or at the banks of



1 a river but is most often located entirely underground at a depth of 200 to 500 m while having a thickness of several tens of meters. Due to consideration of economy and environmental protection, it is necessary to separate out the oil underground and to extract only the oil from the well. Moreover, since the extraction of oil from a shallow underground layer is accompanied by a danger of subsidence, it is desirable to extract oil only from underground layers lying deeper than 300 m.

Further aspects of the background of the invention and  
 10 the invention of the present application are described with the assistance of the accompanying drawings in which:

Fig. 1 is a schematic sectional view showing a conventional prior art installation of the general type with which the invention is utilized;

Fig. 2 is a cross-sectional view of an insulated pipe joint of the invention;

Fig. 3 is a cross-sectional view showing several joined pipe sections, an electrode and insulated pipe joints in accordance with the invention; and

20 Figs. 4-7 are a series of cross-sectional views illustrating the use of insulating coatings in accordance with the invention.

Fig. 1 illustrates the heating of an oil sand layer by electrodes coupled to a power supply. In Fig. 1, reference numerals 1 and 11 indicate main guide pipes made of steel, 2 and 12 indicate insulators joined to the main guide pipes 1 and 11, 3 and 13 indicate electrodes joined to the insulators 2 and 12, perforations are formed in the electrodes 3 and 13, and 4 and 14 indicate cables for feeding an electric current to the electrodes 3 and 13. This assembly is hereinafter called together the  
 30

1168283

1 "electrode device". Reference numeral 5 indicates a power source, 6 indicates an oil sand layer, 7 indicates an electric current flowing between the electrodes 3 and 13, 8 indicates the ground surface, 9 indicates an overburden layer, and 10 indicates a layer below the oil sand layer.

When a voltage is applied to the electrodes 3 and 13 which are buried in the oil sand layer 6 from the power source 5 through the cables 4 and 14, the current 7 flows in accordance with the electric resistance of the oil sand layer

10 6 as a result

20

30

1168283

of which the oil sand layer 6 is heated by Joule or resistance heating. Although, the current 7 partially flows into the overburden layer 9 and the layer 10, the leakage is maintained at a low level because the insulators 2 and 12 are interposed between  
5 the main guide pipes 1 and 11 and the electrodes 3 and 13. After the oil sand layer 6 has been warmed, the power supply is interrupted. Hot water or water vapors at a high temperature under a high pressure are then forced from the upper inlet of one main guide pipe 1 of the electrode device and flow through the oil  
10 sand layer 6 until they come out of the other main guide pipe 11 carrying the oil. In order to improve the flow rates of the hot water or the hot pressure water vapors, perforations are formed in the electrodes 3 and 13.

Since the upper portions of the insulators 2 and 12  
15 are connected to the main guide pipes 1 and 11 and the lower portions are connected with the electrodes 3 and 13, a downward tensile stress is always applied to the insulators. Moreover, since the assembly can be at a temperature as high as 250°C to 300°C, the insulators should be able to withstand such  
20 temperatures. Also, since the insulators 2 and 12 are buried underground as deep as several hundred meters with the electrodes 3 and 13 suspended from their lower ends with the upper ends thereof connected to the main guide pipes 1 and 11, the insulators 2 and 12 will almost certainly contact or collide with the well  
25 walls while they are lowered into the well. Because of the

1168283

great total weight, any slight contact will impose a high mechanical impact upon the insulators 2 and 12. Therefore, the insulators 2 and 12 are required to be able to withstand anticipated levels of mechanical impact.

5           In an electrode device which heats an oil sand layer when it is supplied with an electric current, a major problem is that the electric resistance in the oil sand layer is approximately equal to the overburden layer. Since these electric resistances differ depending on place and conditions, they cannot generally  
10 be precisely stated. However, average values are  $100\Omega\text{-m}$  for the oil sand layer and  $100\text{-}150\Omega\text{-m}$  for the overburden layer. As a result, if an electric current is supplied to two electrode devices which are constructed by connecting electrodes to guide pipes made of steel pipes and by disposing those electrodes in the oil sand  
15 layer, most of the current will be consumed in the overburden layer. In order to avoid this problem, it is necessary either to cover the surfaces of the guide pipes with an insulating coating or to insulate the electrodes from the guide pipes.

          Various attempts have been made to provide insulators  
20 which satisfy the aforementioned requirements. In one such attempt, flanged tubular members made of metal are coated with an organic resin which provides a high resistance to heat. An appropriate material is polytetrafluoroethylene resin (for example "Teflon<sup>TM</sup>" which is trade name of du Pont). With this  
25 construction, insulating members are provided which are satisfactory in their ability to withstand a suspending load

1168283

and mechanical impact forces. However, it has proved quite difficult to coat the flange portions satisfactory with the insulating material. Moreover, even if satisfactory insulating characteristics are provided at room temperature, the insulating coating has a tendency to separate, especially around the flange portions, due to repeated thermal expansion and contraction such as is typically encountered in normal operating conditions. If the insulation coating is broken or caused to flake off, the insulators thus produced become useless.

10 In a second attempt, porcelain material has been used for forming the insulators. However, it is also necessary in constructing the insulators to take into account the requirement for providing water and oil tight characteristics with respect to the connection between the main guide pipes 1 and 11 and the  
15 electrodes 3 and 13 as well as between the insulating member. The connection has generally been made by shrink fitting metal pipes on the outer peripheral surface of the porcelain pipe and then connected with other metal pipes ordinary techniques such as welding or attachment with bolts. With this construction,  
20 although the water and oil tight characteristics may be acceptable at room temperature, the strength of the shrink-fitted joints tends to drop as the temperature is increased so that the ability to support the suspended load is correspondingly lowered. Moreover, breakage of the porcelain may take place as a result  
25 of the stress imposed upon the leading end portions of the shrink-

1168283

fitted areas. In order to eliminate such drawbacks, there has been proposed the use of a porcelain pipe having ends formed as flange portions with the flange portions fastened to metal pipes with packings interposed between the contact surfaces.

5 With this construction, the above-stated requirements are met at room temperature. However, the water and oil tight sealing tends to deteriorate upon repeated thermal expansion and contraction. Moreover, porcelain intrinsically lacks strength against mechanical impact forces. Thus, it has a high tendency  
10 to be broken by a mechanical impact force such as is ordinarily encountered while the assembly is lowered through the well. Thus, the provision of a porcelain insulator suffers from the unavoidable defect that there is a high tendency of breakage.

Yet further, insulators formed of organic polymeric  
15 compounds have been proposed. Although such compounds may have a high strength at room temperature and are quite good electrical insulators, most of the compounds of this general class are not particularly heat resistant. Specifically, very few compounds of this type are known which are resistant to hot water or water vapor at high temperature and under high pressure.

SUMMARY OF THE INVENTION

In accordance with the invention, there is provided an electrode device for electrically heating underground deposits of hydrocarbons including a plurality of well pipe sections, an electrode adapted to be disposed in an underground deposit of hydrocarbons for supplying an electric current to the underground deposits, a plurality of insulating pipe joints each including a first tubular member having a flange portion at one end thereof, a second tubular member having a cap portion at one end thereof adapted to be received in the flange portion of the first tubular member with a gap therebetween and an insulating member disposed in the gap between the flange portion and the cap portion for hermetically coupling the first and second tubular members while electrically insulating them from one another and with the insulating pipe joints being used to couple at least some of the pipe sections together and the electrode to one of the pipe sections, and a cable connected to the electrode for supplying an electric current thereto.

At least some of the insulating pipe joints can be interconnected. The insulating member of each of the insulated pipe joints includes a first insulating portion disposed in the gap between the flange portion in the cap portion and second insulating portions disposed adjacent inner and outer surfaces of the tubular members with the first and second insulating portions being formed integrally with each other. Preferably, the

## 1168283

1 insulating member of each of the insulated pipe joints is made of a glass-mica molding formed from powders of glass and mica. An insulating coating may be provided on at least a portion of the outer surface of the insulated pipe joints. This coating may be a resin of polytetrafluoroethylene, a resin of diphenyl oxide. Moreover, a protective layer of insulation can be provided around at least a portion of the insulating coating. The protective layer may be an inexpensive material such as polyethylene, polypropylene or polyvinyl chloride.

10 Further objects and advantages of the invention will appear from the following description taken together with the accompanied drawings.

### DESCRIPTION OF THE PREFERRED EMBODIMENTS

In accordance with the invention, there is provided an electrical heating electrode device which is entirely free of the above-mentioned drawbacks. A preferred embodiment of the electrode device of the invention will be described in detail, first with reference to Fig. 2 which shows a cross-sectional view of an insulated pipe joint 21 which is utilized with the  
20 electrode device of the invention.

The pipe joint generally designated 21 in Figure 2 comprises four basic elements:

a first tubular member 22, a second tubular member 33, a cylindrical sleeve-like cover member 29, and an insulating member 35.

The first tubular member 22 comprises a cylindrical tubular portion 23 with a radially outwardly extending flange portion 24 at a lower end as shown.

The second tubular member 33 comprises a cylindrical  
30 tubular portion 30 with a radially outwardly extending hub portion



# 1168283

1 25 at an upper end as shown. The interior diameter of tubular portion 30 of the second tubular member 33 is shown identical to the interior diameter of tubular portion 23 of the first tubular member 22.

Hub portion 25 of the 2nd tubular member 33 is provided with an internal annular recess 31 as shown. Hub portion 25 is also provided with external threads 32 which mate with threads 28 on cover member 29 to be described.

10 Sleeve-like cover member 29 comprises a cylindrical, tubular, drum-like portion 26 with internal threads 28 at one lower end as shown in Figure 2 and a radially inwardly extending cap portion 27 at the other upper end. As shown, tubular portion 26 has a larger internal diameter than the external diameter of flange portion 24 of the first tubular member 22 so as to provide a gap therebetween to be occupied by insulating member 35. Cap portion 27 of cover member 29 has an internal diameter larger than the external diameter of tubular portion 23 of the first tubular member 22 so as to form a gap therebetween. The internal diameter of cap portion 27 is smaller than the external diameter of flange portion 24 of the first tubular member 22.

20 preferably the first tubular member 22, second tubular member 33 and cover member 29 are made from steel.

Insulating member 35 includes an outer circumferentially insulating portion 36 which surrounds external surfaces of tubular portion 23 of first tubular member 22 and an inner circumferentially insulating portion 37 which fits inside the internal annular recess 31 of hub portion 25 of the second tubular member 33. The inner insulating portion 37 has the same internal diameter as that of tubular portion 30 of the second tubular member 33. As may be seen, insulating member 35 comprises an integral

1168283

1 member extending from portion 36 thereof to portion 37 thereof. Integral insulating member 35 thus spaces surfaces of the first tubular member 22 from surfaces of second tubular member 33 and cover member 29 by a gap occupied as seen in Figure 2 by insulating member 35. Insulating member 35 insulates first tubular member 22 from contact with second tubular member 33 and cover member 29.

10 With cover member 29 screwed down onto second tubular member 33 as shown in Figure 2, flange portion 24 of first tubular member as encased by insulating member 35 is sandwiched between cover member 29 and the upper end of hub portion 25 of the second tubular member 33, whereby insulating member 35 may form a hermetic seal between first tubular member 22 and second tubular member 33.

By screwing cover member 29 onto second tubular member 33, first tubular member 22 may be firmly, sealably coupled to second tubular member 33 yet insulatively isolated therefrom.

20 In assembly, first tubular portion 22 may be inserted through cover member 29 following which cover member 29 may be screwed onto second tubular portion 33. The insulating member 35 may be seen to occupy a gap between the first tubular member 22 and the combination of the second tubular member 33 and cover member 29.

30 Preferably, the entire insulating member is made of a composition of glass and mica and is formed by a molding process. The insulating member is formed by heating a mixture of powders of glass and mica to a sufficiently high temperature that the mixture becomes fluid. Once the mixture is fluid, it is pressure molded using a mold of appropriate shape. The formation of the insulating member 35 will be described in more detail.

1168283

1           The first tubular member 22 and the second tubular member 33 are assembled to be positioned as shown in Fig. 2 and are then heated to a predetermined temperature. The two tubular members at the elevated temperature are fitted into a mold. Next, a mixture of glass and mica powders is prepared by pre-molding the mixture into the form of a preliminary molded member of a cylindrical shape which will fit in the gap between the tubular portion 23 of the first tubular member 22 and cover member 29. The preliminary molded member is heated to a predetermined  
10   temperature and fitted in the gap in a heated condition. Next, a pressure is applied to the preliminary molded member before it cools to force the material of the member to flow into the gap between the first and second tubular members and into the internal annular recess 31 in the second tubular member 33.

          For the material of the preliminary molded member, 45 wt% of glass powder prepared by pulverizing a glaze used for enamel coating steel objects, commercially available as Product No. 2312 of Nippon Ferro, Ltd., to a size of 200 mesh mixed with  
20   55 wt% of mica powder of synthetic phlogopite of a size of 60 to 200 mesh. 5 wt% of water is added to the resultant mixture to wet it so it can be molded. 1500 gm of the wetted mixture is molded using a cold pressure molding process to form a cylindrically shaped body using a mold (not shown). The preliminary molded member was disposed in a drier at 120°C for two hours to dry it prior to its use in forming the insulating member 35.

          As described above, the cover member 29 and the hub portion 25 are joined by screw threads. However, the invention is not limited thereto as the cover member 29 and the hub portion 25 can be joined by welding.

30           In an alternate embodiment, the cap portion 27 of

# 1168283

- 1 the cover member 29 is divided into four quadrants two of which are removed. The flange portion 24 of the first tubular member 22 is then cut such that the remaining part of the flange portion 24 can fit through the two removed quadrants of the cap portion 27 so that the flange portion 24 can be located under the cap portion 27 of the cover member 29.

- With the insulated pipe joint described above, a tensile force imposed on the ends of the joint is converted into a compressive force which acts between the cap portion 27 and  
10 flange portion 24. Since the compression strength of the insulating member 35 of the type described is much greater than its tensile strength and since the force per unit area can be suitably set by adjusting the extent of the area on which the compressive forces are applied, the resulting assembly is quite strong and able to withstand high tensile forces imposed on the ends of the joint.

- At high temperatures, for instance  $300^{\circ}\text{C}$ , the heat resistant characteristics of the insulating member are primarily determined by the thermal characteristics of the glass material  
20 used as the starting material. Particularly, the transition temperature of this material is important. If the transition

temperature is, for instance, in a range of 550 °C to 600 °C. a high mechanical strength for the overall assembly will be preserved to a temperature of at least 300°C.

With respect to the resistance to mechanical impact forces, the mica powder which is used to form the insulating member is composed of particles having a flat shape wherein the ratio of the diameter to the thickness of a single scale particle is generally in a range of 30 to 50:1. Due to the presence of the scale particles, the molded insulating member has a laminated form thereby providing it with a high elasticity. This high elasticity would not be present if the insulating member were formed only of glass powders. Due to the laminated construction, the insulating member is provided with a much greater resistance to repeated temperature changes and mechanical impact forces than is a prior art type of insulating member made of an inorganic compound. Therefore, the insulating member produced in accordance with the invention is sufficiently strong that it can withstand the typical impact forces which are encountered during the use of the structure.

Next, the construction of a preferred embodiment of an electrode device of the invention utilizing the above-described insulated pipe joint 21 will be given with reference to Fig. 3. Reference numerals 1 to 4 used in Fig. 3 indicate similar components as those of Fig. 1. The righthand half of Fig. 3 shows the completed structure of the insulated pipe joint

1168283

21. As shown in the figure, the insulating member 2 includes two insulated pipe joints 21. One end of the insulating member 2 is connected to the pipe 1 and the other to the electrode 3. These connections may be made by well-known techniques such as welding or by the use of screw threads.

As, in accordance with the invention, the completed insulated pipe joint 21 has a common throughhole of constant internal diameter, the assembly and use thereof is quite easy. For instance, the provision of the above-described partitions is quite simple. Of course, more than two insulated pipe joints 21 can be provided as needed. Also, one of the pipe joints 21 can be connected directly to the pipe 1.

If needed, such as in the case brine having a high salt concentration is used, the outer surface of the insulated pipe joint 21 can be covered with a coating 41 of an organic substance having a sufficiently high heat resistant property. This is shown in the left-hand part of Fig. 3. For example, the coating 41 can be formed by shrink fitting a "Teflon<sup>TM</sup>" tube.

As described above, in accordance with the invention, the pipes and the electrodes are connected through the insulated pipe joints. Tensile forces applied at the ends of the insulated pipe joints are converted into compression forces which act between the cap portions and the flange portions thereof. Since the compression strength of the insulating member is much greater than the tensile strength thereof, the overall electrode device

of the invention has a quite high mechanical strength and can withstand high pressures and strong mechanical impact forces so that it can be used under severe operating conditions often encountered in oil well application.

5            Yet further, the coating 41 and the insulating members  
:    2 and 12 of the electrode can be formed from other materials.  
To determine what materials are best for these members, tests  
were conducted to investigate the resistance of various organic  
polymeric compounds to hot water and water vapor at high temperature  
10 and under high pressure. The compounds investigated are listed in  
Table 1 herein.

          Regarding the tests, test pieces of each of the materials  
were placed in quartz test tubes filled with pure water. These  
test tubes were placed in a 2-liter autoclave containing pure  
15 water. The autoclave was held at 280°C at an internal pressure  
of 68 kg/cm<sup>2</sup> for a period of 10 days. The autoclave was then  
cooled to a room temperature and the test pieces were checked for  
appearance. The results are presented in Table 2 from which it  
can be seen that hot water and steam had a much more adverse affect  
20 than dry heat. Of the materials tested, only polytetrafluoroethylene  
resin and diphenyl oxide resin were acceptable.

          A coating of water and steam resistant resin can be  
formed around the pipe 1 by repeatedly applying coatings of the  
material and baking the assembly until the desired thickness is

obtained. Also, a coating of the heat resistant resin can be formed by first preparing a tube of the resin having an inside diameter slightly larger than the outside diameter of the pipe 1 and then slipping the tube over the pipe 1. If the resin is in the form of a sheet or tape, it may be wound directly around the pipe 1 and then fusion-bonded if necessary. As described above, a heat-shrinkable tube of polytetrafluoroethylene can be slipped over the pipe 1 and heated to fit it tightly to the pipe.

As discussed above, when the assembly including the electrode is inserted into the oil well, there is unavoidable contact with the inner wall of the well so that the heat resistant insulating coating may be damaged. To prevent this, protective coating of insulation 16 may be formed around the insulation 15 as shown in Fig. 5. Since the protective coating of insulation 16 may melt or collapse if the electrode is exposed to high temperatures, it can be made of an inexpensive material such as polyethylene, polypropylene or polyvinyl chloride.

Typically, the total length of the guide pipe 1 is 200 to 500 m. However, a single section of the steel pipe that makes up the guide pipe 1 is only about 10 m in length. To join the pipe sections, each pipe section is provided with a taper thread on one end and the pipe sections are joined by screwing them together. An insulating coating must also be formed around the joined parts of the pipe sections and on the surface of the coupling. To accomplish this, as shown in Fig. 6, steel pipes



1168283

1A and 1B are covered with the coating of heat resistant insulating material 15A and 15B and are joined by a coupling 17. A coating of heat resistant insulation 15C is formed around the coupling extending into adjacent areas. A heat-shrinkable tube of a polytetrafluoroethylene is particularly suitable in this case.

To protect the insulating coatings from direct contact with the inner wall of the well, steel pipe sections 1A and 1B covered with the coating of heat resistant insulating material 15A and 15B and protective coatings of insulation 16A and 16B are first joined through the coupling 17. Thereafter, the coupling 16 is coated with the heat resistant insulation 15C and then a layer of 16C is formed around the coupling and in the adjacent areas as shown in Fig. 7.

1168283

1A and 1B are covered with the coating of heat resistant insulating material 15A and 15B and are joined by a coupling 17. A coating of heat resistant insulation 15C is formed around the coupling extending into adjacent areas. A heat-shrinkable tube  
5 of a polytetrafluoroethylene is particularly suitable in this case.

To protect the insulating coatings from direct contact with the inner wall of the well, steel pipe sections 1A and 1B covered with the coating of heat resistant insulating material  
10 15A and 15B and protective coatings of insulation 16A and 16B are first joined through the coupling 17. Thereafter, the coupling 16 is coated with the heat resistant insulation 15C and then a layer of 16C is formed around the coupling and in the adjacent areas as shown in Fig. 7.

1168283

Table 1

Sample	Chemical name (abbr.)	Manufacturer	Item No.	Form	Thickness	Method of sample preparation
A	Polytetrafluoroethylene resin (PTFE)	Nitto Electric Industrial Co., Ltd.	No. 900	Tape	0.1	Cutting
B	Tetrafluoroethylene-hexafluoropropylene copolymer resin (FEP)	"	No. 945	Tape	0.125	"
C	Tetrafluoroethylene-perfluoroalkylvinyl ether copolymer resin (PEA)	"	No. 460	Tape	0.125	"
D	Polyimide resin	Toray Industries, Inc.	Kapton	Film	0.05	"
E1	Diphenyl oxide resin	Ryoden Chemical Industries Co., Ltd.	V505-50	Liquid	0.05	Baking after application to tinplate
E2	" + mica powder (20 wt%)					
F	Diphenyl oxide resin - laminated with glass cloth	"	PGD-637	Sheet	2 mm	Cutting

<u>Sample</u>	<u>Chemical name (abbr.)</u>	<u>Manufacturer</u>	<u>Item No.</u>	<u>Form</u>	<u>Thickness</u>	<u>Method of sample preparation</u>
G	Silicone resin	Shinetsu Chemical Industry Co., Ltd.	KR-280	Liquid	0.05	Baking after application to tinplate
H	Silicone resin-laminated with glass cloth	Nikko Kagaku K.K.	NL-SG-13	Sheet	3 mm	Cutting
I	Epoxy resin-laminated with glass cloth	"	NL-EG-23	Sheet	3 mm	Cutting
J	Unsaturated polyester resin-laminated with glass cloth	"	NL-POGN	Sheet	3 mm	Cutting

1168283

1168283

Table 2

<u>Sample</u>	<u>Appearance</u>
A	OK.
B	Turned into a lump.
C	Do.
D	Collapsed
E1	OK.
E2	Do.
F	Do.
G	Turned into a lump.
H	Glass whitened (Resin came apart)
I	Do.
J	Do.

1168283

WHAT IS CLAIMED IS:

1. An electrode device for electrically heating underground deposits of hydrocarbons comprising: a plurality of well pipe sections; an electrode adapted to be disposed in an underground deposit of hydrocarbons for supplying an electric current  
5 to said underground deposit; a plurality of insulated pipe joints each including a first tubular member having a flange portion at one end thereof, a second tubular member having a cap portion at one end thereof adapted to be received in said flange portion of said first tubular member with a gap therebetween, and an  
10 insulating member disposed in said gap between said flange portion and said cap portion for hermetically coupling said first and second tubular member and for electrically insulating said first and second tubular members from one another, said insulated pipe joints being operatively disposed to couple at least some  
15 of said pipe sections and said electrode while electrically insulating said at least some of said pipe sections and said electrode; and a cable connected to said electrode for supplying an electric current to said electrode.

2. The electrode device as set forth in claim 1 wherein at least some of said insulated pipe joints are interconnected.

3. The electrode device as set forth in claim 1 wherein said insulating member of each of said insulated pipe joints comprises a first insulating portion disposed in said gap between said flange portion and said cap portion, and second insulating

portions disposed adjacent inner and outer surfaces of said tubular members, said first and second insulating portions being formed integrally with each other.

4. The electrode device as set forth in claim 1 wherein said insulating member of each of said insulated pipe joints is made of a glass-mica molding formed from glass and mica powders.

5. The electrode device as set forth in claim 1 further comprising an insulating coating provided on at least a portion of an outer surface of said insulated pipe joints.

6. The electrode device as set forth in claim 5 wherein said insulating coating is polytetrafluoroethylene.

7. The electrode device as set forth in claim 6 wherein said insulating coating comprises a resin of thermally shrinkable polytetrafluoroethylene.

8. The electrode device as set forth in claim 5 wherein said insulating coating comprises a resin of diphenyl oxide.

9. The electrode device as set forth in any of claims 5-7 further comprising a protective layer of insulation upon at least a portion of said insulating coating.

10. The electrode device as set forth in any of claims 5-7 further comprising a protective layer of insulation upon at least a portion of said insulating coating, said layer of protective insulation comprising a material selected from the group consisting of polyethylene, polypropylene and polyvinyl chloride.

1168283

11. An electrode device for electrically heating underground deposits of hydrocarbons comprising a plurality of interconnected well pipe sections, an electrode adapted to be disposed in an underground deposit of hydrocarbons supplying electric current to said underground deposit, at least one insulated pipe joint including a first tubular member comprised of a well pipe section having a flange portion at one end thereof, a second tubular member comprised of said electrode disposed in alignment with said first tubular member, a cover member carried by said second tubular member having a cap portion at one end thereof disposed in overlying relation to said flange portion above said first tubular member with a gap therebetween, an insulating member disposed in said gap between said flange portion and said cap portion for hermetically coupling said first and second tubular member and for electrically insulating said first and second tubular members from one another, cable means connected to said electrode for supplying an electric current to said electrode and an insulating coating provided on at least an outer surface of said insulating pipe joint.